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INSTRUMENTED TEST SITE FOR INFRARED BACKGROUNDS

by

A. O. POULIN and A. E. KRUSINGER



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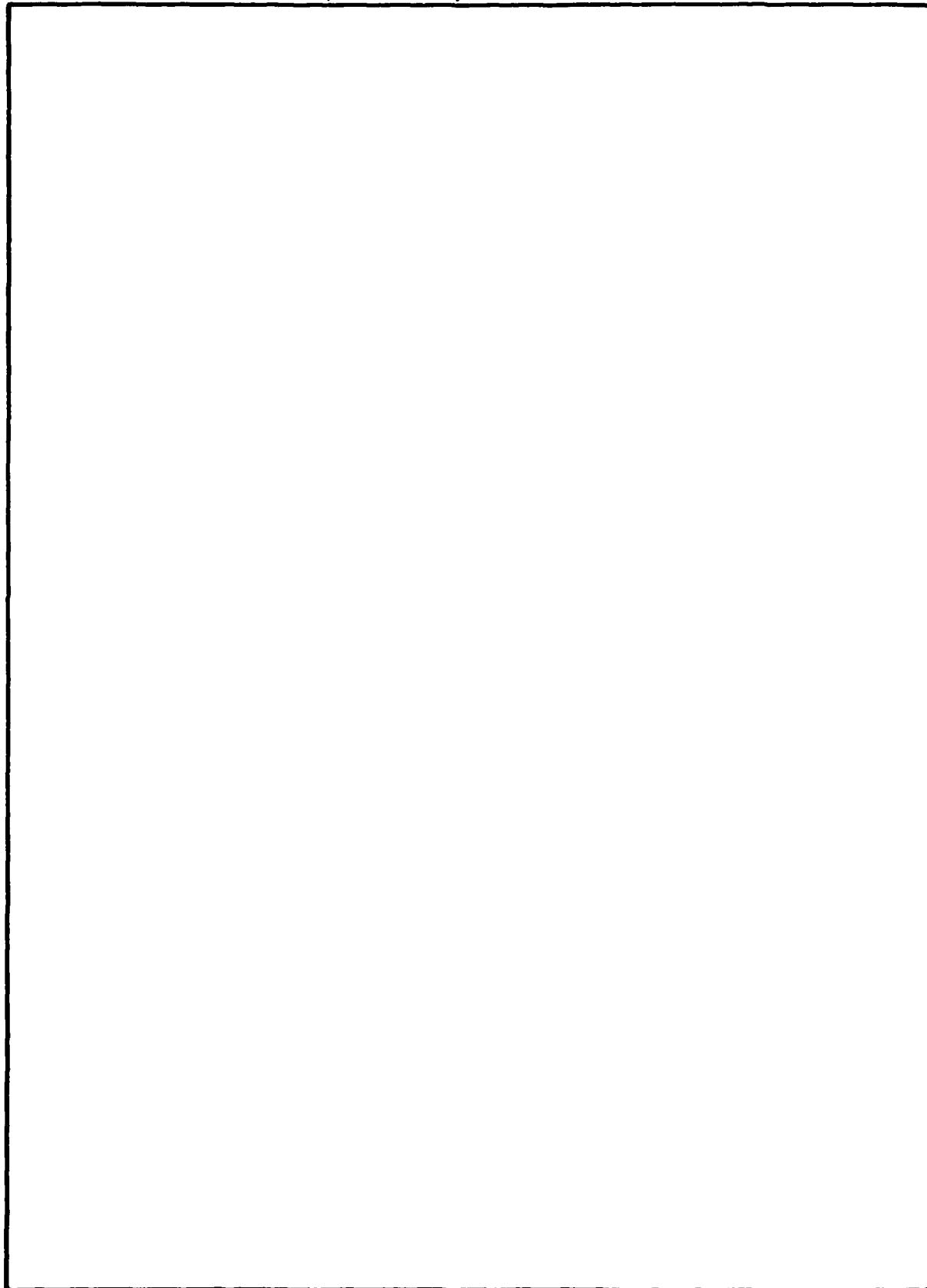
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INSTRUMENTED TEST SITE FOR INFRARED BACKGROUNDS

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July 1980

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ABSTRACT

A test site for the study of soil moisture and infrared backgrounds has been established at Ft. Belvoir, VA. A computer-controlled, tower-mounted radiometer (8-14 μ m) measures the radiance of four test plots, and a 100-channel data system measures environmental parameters. Some test results are presented.

1. INTRODUCTION

Since the start of terrain related infrared studies in the 50s, great volumes of such data have been collected at numerous locations for various short periods, and much has been learned from this work. Also, during this period considerable effort has gone into the development of surface temperature prediction models. The past decade has seen some very good work involving long-term studies relative to the assessment of soil moisture, particularly with respect to irrigated crops. Although the soil moisture studies are relevant to the study of infrared backgrounds, their concentration on single crops during the growing season precludes the acquisition of sufficient data for the more general problem of infrared backgrounds, particularly as they occur in nonagricultural areas.

The purpose of this paper is to describe a test site for the study of soil moisture and infrared backgrounds, to present briefly some of our recent observations, and to invite anyone who may be interested to visit the site and discuss topics of common interest. The site is located at the U. S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA.

2. SITE DESCRIPTION

The basic capability that the site provides is that of continuous observation of the radiance of four test plots from a computer-controlled, tower-mounted radiometer, and of the environmental parameters that influence the radiation. Figure 1 is a photograph of the test site taken from our 88-foot mobile tower. Note the four test plots and the 15 m tower supporting the radiometer.

Figure 2 is a diagram of the test site showing its size, the surface condition of each plot, and the location of the instrument towers.

Figure 3 is a block diagram of the automatic data system. One hundred channels of data may be recorded in two modes via the data logger and the interfaced, 186K byte computer: (1) all the raw data as voltages or degrees Celsius on 7 channel, 1/2 inch digital tape, and (2) partially reduced data on the computer's digital tape cartridges. Selected parameters may be plotted immediately after measurement on either the computer's CRT or a plotter/printer. Hard copy of the CRT display may be obtained when desired. At the present time the system is programmed to do a data scan every 12 minutes. This could be reduced to about 3 minutes, or increased beyond any practical limit. Table I lists the measurements that can be made automatically. Additionally, six implanted microwave sensors are used to make manual measurements of volumetric soil moisture. A few selected parameters, such as wind, incoming radiation, and test plot radiance may be monitored in analog form via strip chart recorders.

TABLE I. AUTOMATICALLY RECORDED MEASUREMENTS

Radiance of test plots
Precipitation amount and temperature
Air temperature profiles to 3 m
Incoming shortwave radiation
Incoming longwave radiation
Net shortwave and total radiation at each test plot
Wind at 120 cm (2 locations)
Wind at 15 m (1 location)
Soil temperatures (1, 4, 10, 20, 40, 80 and 160 cm)
Soil water tension (15, 30, 60, 90 cm in each plot)
Various system status parameters

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This computational and graphic capability, along with the data logger, provides a powerful means of witnessing environmental conditions and the consequent radiance of four surfaces as they occur, and, in addition to the system control software, the computer can retain the previous 300 observations of approximately 50 data channels.

3. SOME EXPERIMENTAL RESULTS

An interesting example of an unusual sequence of measurements involved the

thermal contrast between the bare soil and vegetated plots that occurred during a four hour period of rain on 23 October 1979. Figure 4 shows a plot of the cumulative rainfall and precipitation rate. Figure 5 shows the radiant temperature of the four plots for 0.2 day (4.8 hours) that included the rain period. The sudden temperature reduction at approximately 296.655 suggests that this was the actual time at which the rain started, but the initial intensity was apparently too low to trigger the recording rain gauge. The rain started with the onset of darkness, and the initial slope of the temperature curves is due to normal end-of-the-day cooling. The following observations may be made from Figure 5.

1. Following the initial drop, the temperatures and temperature differences diminished only slightly over the initial three hours or so.

2. After almost three hours, when the cumulative precipitation reached 7 mm and the short term rate was about 0.5 mm per hour, the temperatures dropped suddenly, but Plot 2, the bare soil, dropped much less than the vegetated plots.

Figure 6 is a plot of the temperature differences between Plots 2 and 3, 2 and 4, and 4 and 3. Note that when the plot temperatures dropped suddenly during the latter part of the rain period, differences between bare and vegetated areas almost tripled and sustained a large value for a significant period.

In retrospect, it seems reasonable that such a phenomena should occur, but putting reliable numbers on it would not be a trivial task. We intend to continue studying this phenomenon.

Another interesting thermal signature is that of more or less isolated trees, which frequently appear as warm images in nocturnal imagery, particularly evergreens against a snow cover. Unless the spatial resolution is sufficient to delineate shapes clearly, such a tree can easily be mistaken for a vehicle with its engine running. This is basically due to the development of inversions, resulting in the upper parts of objects rising above ground level being immersed in warmer air. But in the case of trees, the question arises as to whether or not air temperature is the only significant factor. During May 1980, we conducted an experiment to take an initial look at this problem.

Figure 7 shows the experiment setup. It included three trees--a live Douglas fir, one cut off at its base, and an artificial Christmas tree--with thermocouples attached to measure air temperatures at four points along the stems and outer edges. Air temperatures near the trees were measured with six thermocouples attached along the length of a 3 m pole. Measurements were made every 12 minutes with our data

system. Two methods of radiometric measurements of the trees were made--with hand-held radiometers, and with the Night Vision and Electro-Optics Laboratories' (NV&EOL) thermoscope, a calibrated digital recording thermal imager. All observations were made at night.

Figure 8 is one of the images generated with the thermoscope. It exemplifies the phenomenon under consideration. The three trees are warmer than the cut grass in the immediate background, and the high trees just below the horizon are warmer than the lower ones in front of them. The dynamic range of this picture is 12 degrees--275 to 287 K. Temperatures of the three trees are in the range of 281 to 285 K, and the immediate grass background varies from about 275 to 281 K. Twenty-two such digitally recorded scenes were obtained over a period of one night, and their analysis is still in progress.

A total of 47 manual radiometric observations of each tree was made on seven nights. These measurements were compared with the air temperatures in the trees and away from the trees. Detailed analyses of these data cannot be presented in this paper, but the results indicate that the regression of radiant temperatures and air temperatures show a statistically significant deviation from a linear relationship. This may be seen in Figure 9. The data support a second order polynomial model in the observed temperature range of 0 to 20° C, but there is reason to speculate that when higher temperatures are included a third order model may be better. We plan to extend these observations over a greater temperature range.

At a later date we hope to be able to perform real-time tests of surface temperature models whereby we would compare computed and observed values as they occur.

If these things interest you, particularly if you have models to test, we should like to have you visit or contact us at our laboratory.

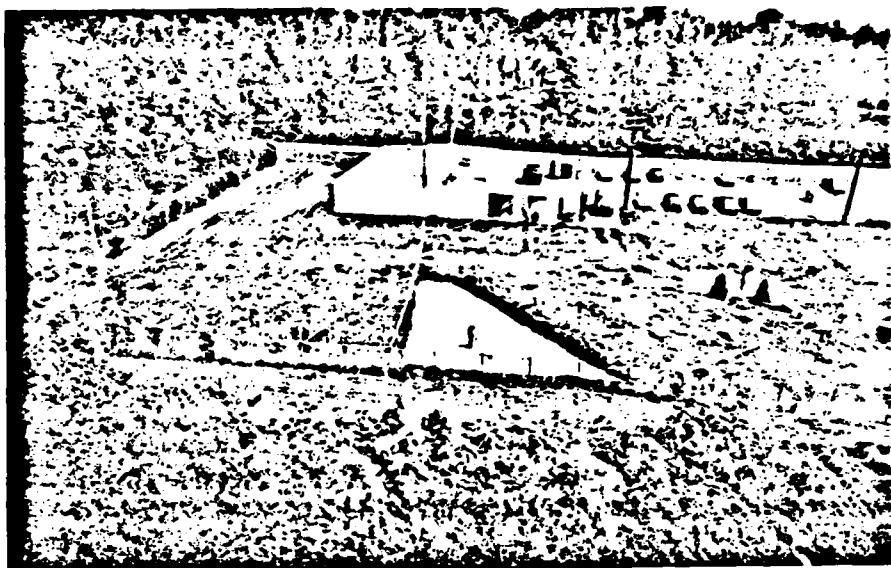


Figure 1. View of test site.

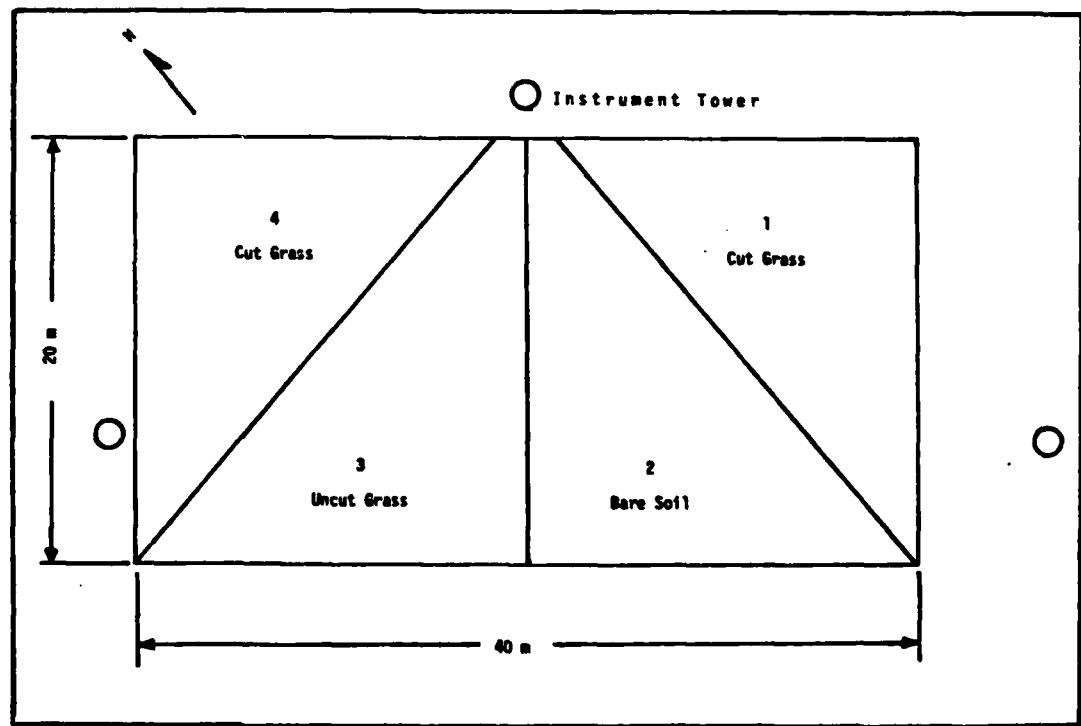


Figure 2. Diagram of test site layout. Infrared radiometer is mounted 40 feet up on the middle tower.

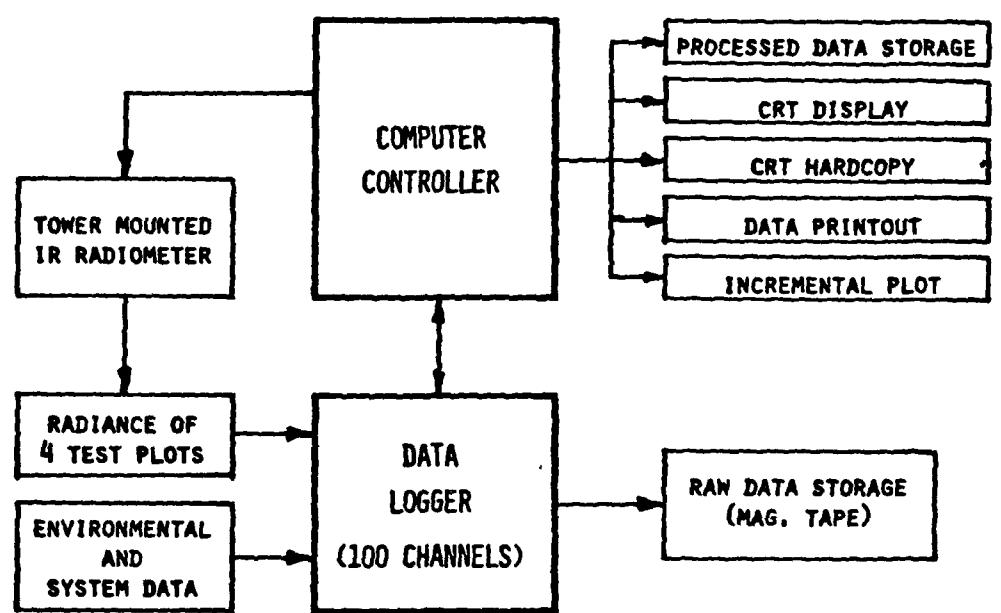


Figure 3. Block Diagram of Data System.

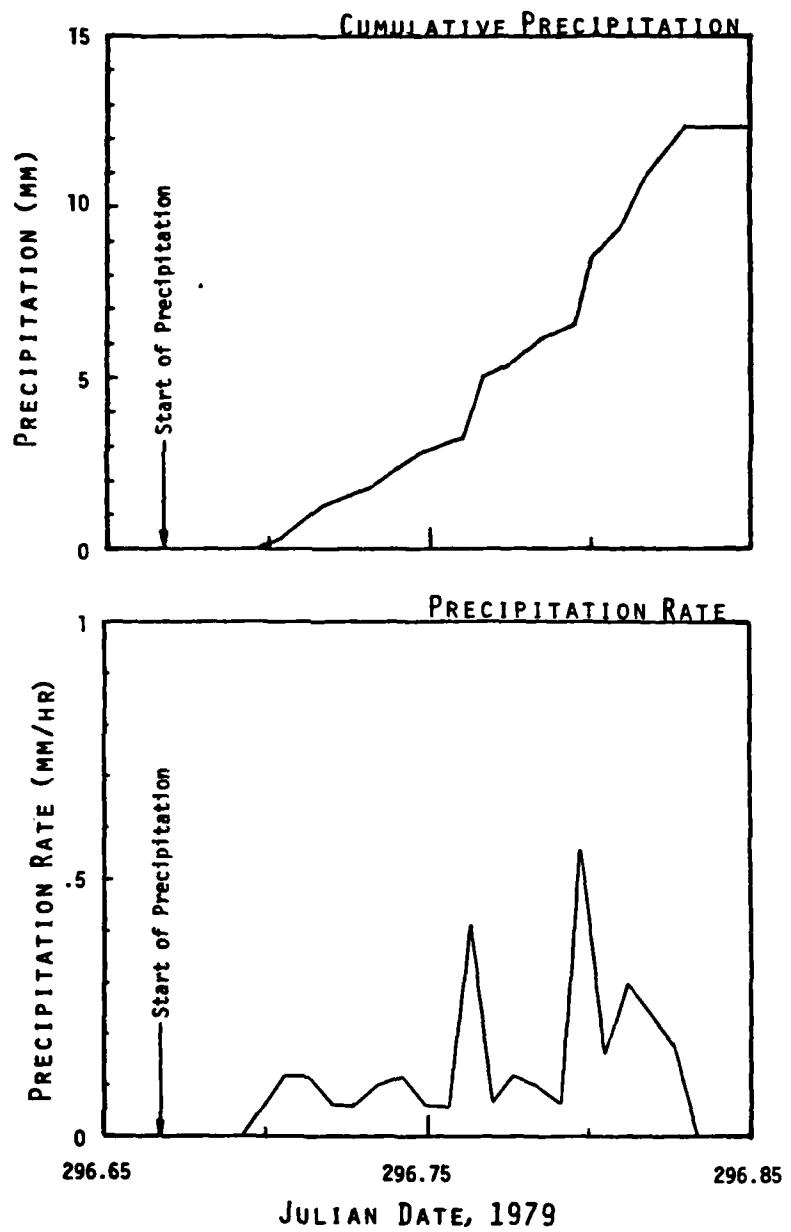


Figure 4. Cumulative rainfall and precipitation rate at the test site, 23 Oct 79.

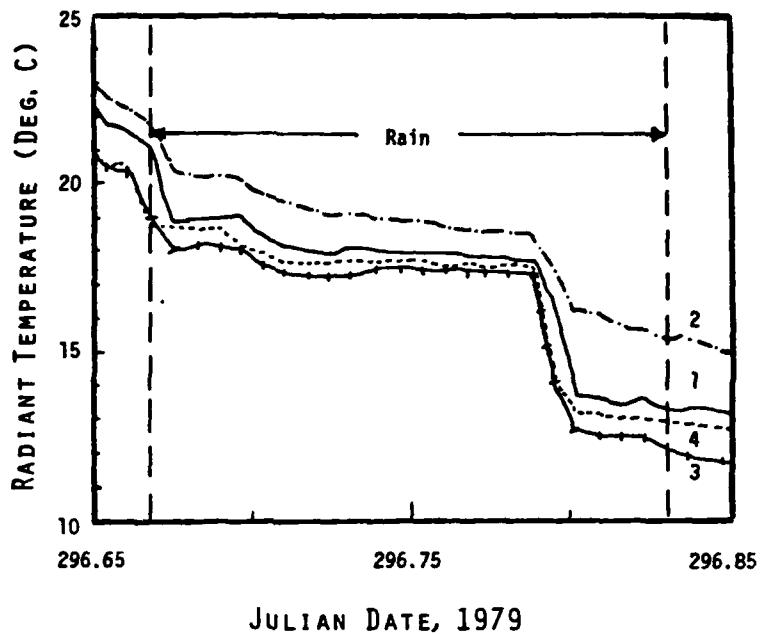


Figure 5. Radiant temperature of the four test plots recorded every 12 minutes for the 0.2 day (4.8 hr.) period during which the rain fell, 23 Oct 79.

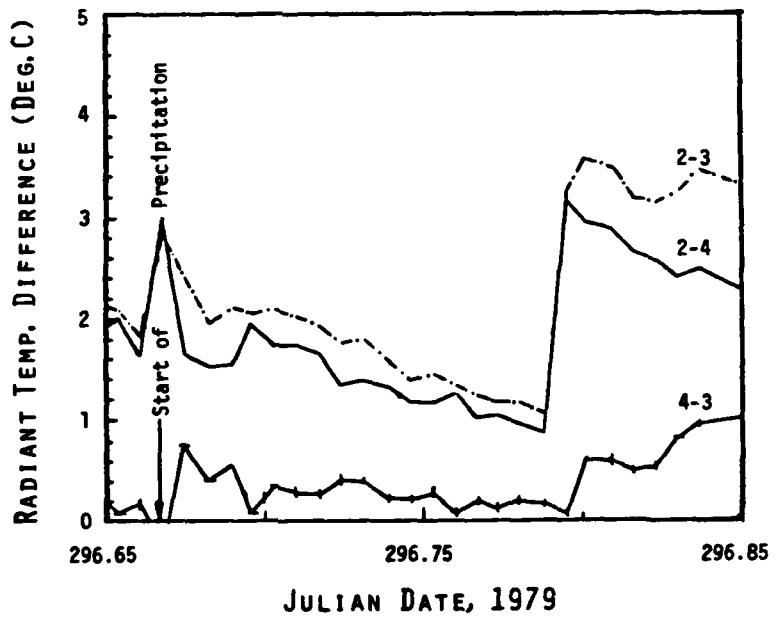


Figure 6. Radiant temperature differences determined from the data of Figure 5.

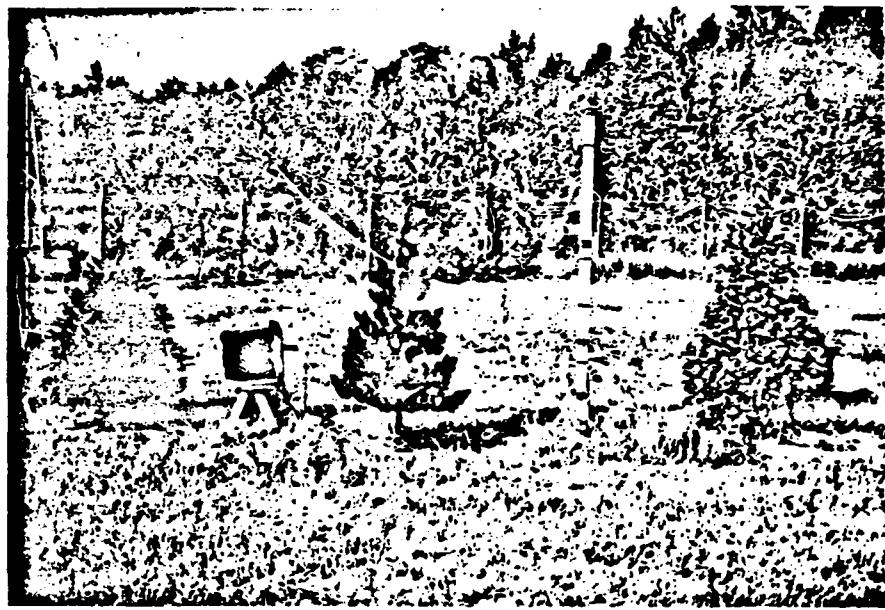


Figure 7. Photograph of experiment setup. L. to R.: dead tree, 18 inch square blackbody, artificial tree (plastic, steel and wood), pole for air temperature measurements, live tree (Douglas fir).



Figure 8. Thermal image of trees recorded with the Night Vision and Electro-Optical Lab thermometer. Picture is a photograph of a digital image display (CRT) in the DIAL system at the Army Topographic Labs. The 12 degree range of the image is divided into 16 grey steps. The middle temperature is for the pixel at the cursor (on the blackbody).

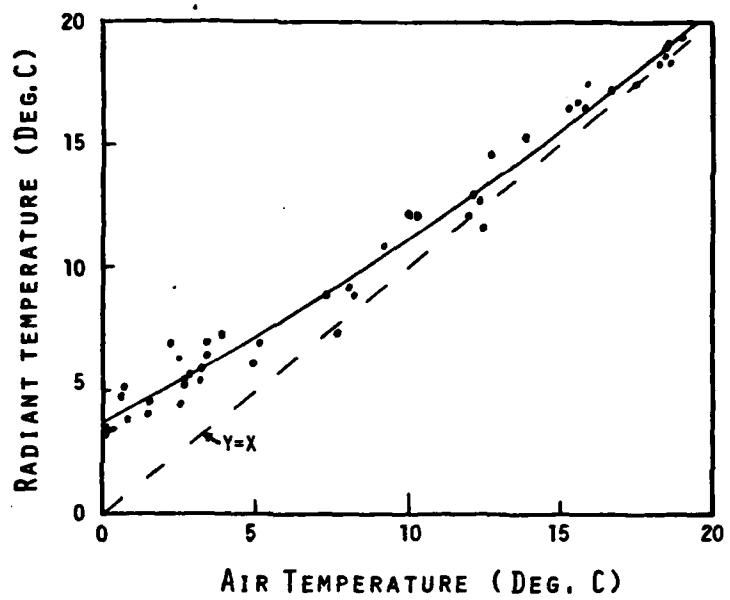


Figure 9. Second-order polynomial regression relating radiant tree temperatures to air temperature.